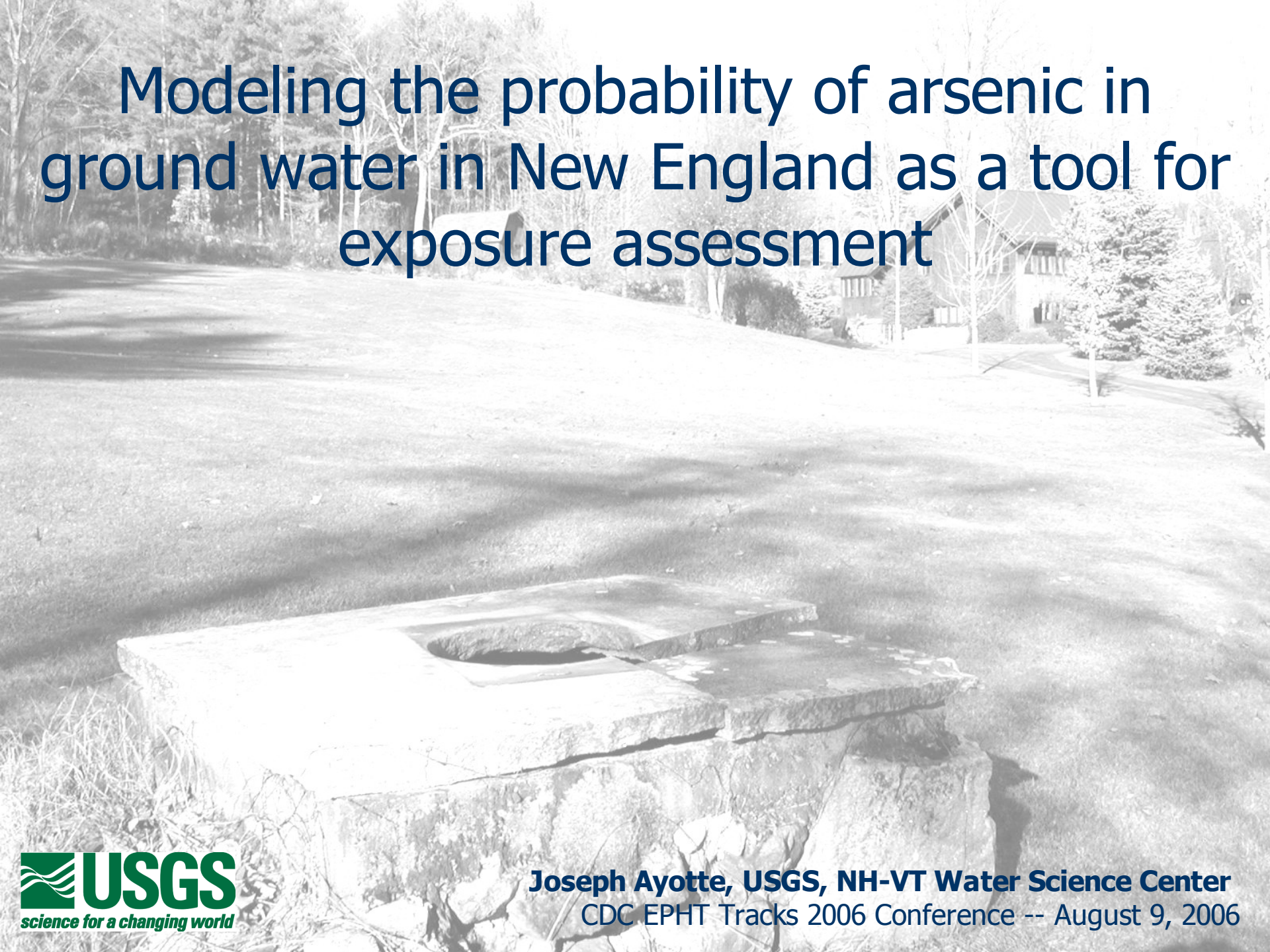
Modeling the probability of arsenic in ground water in New England as a tool for exposure assessment



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Joseph Ayotte, USGS, NH-VT Water Science Center

CDC EPHT Tracks 2006 Conference -- August 9, 2006

Collaborators

- National Cancer Institute—
  - Jay Lubin, Ken Cantor, Dalsu Baris, Debra Silverman
- Colorado State University/NCI,
  - Jay Nuckols
- Dartmouth Medical School,
  - Margaret Karagas
- The New England States
- USGS NAWQA program

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Outline of talk

- Arsenic in New England
- New England Bladder Cancer Study
- New England arsenic model
- Summary

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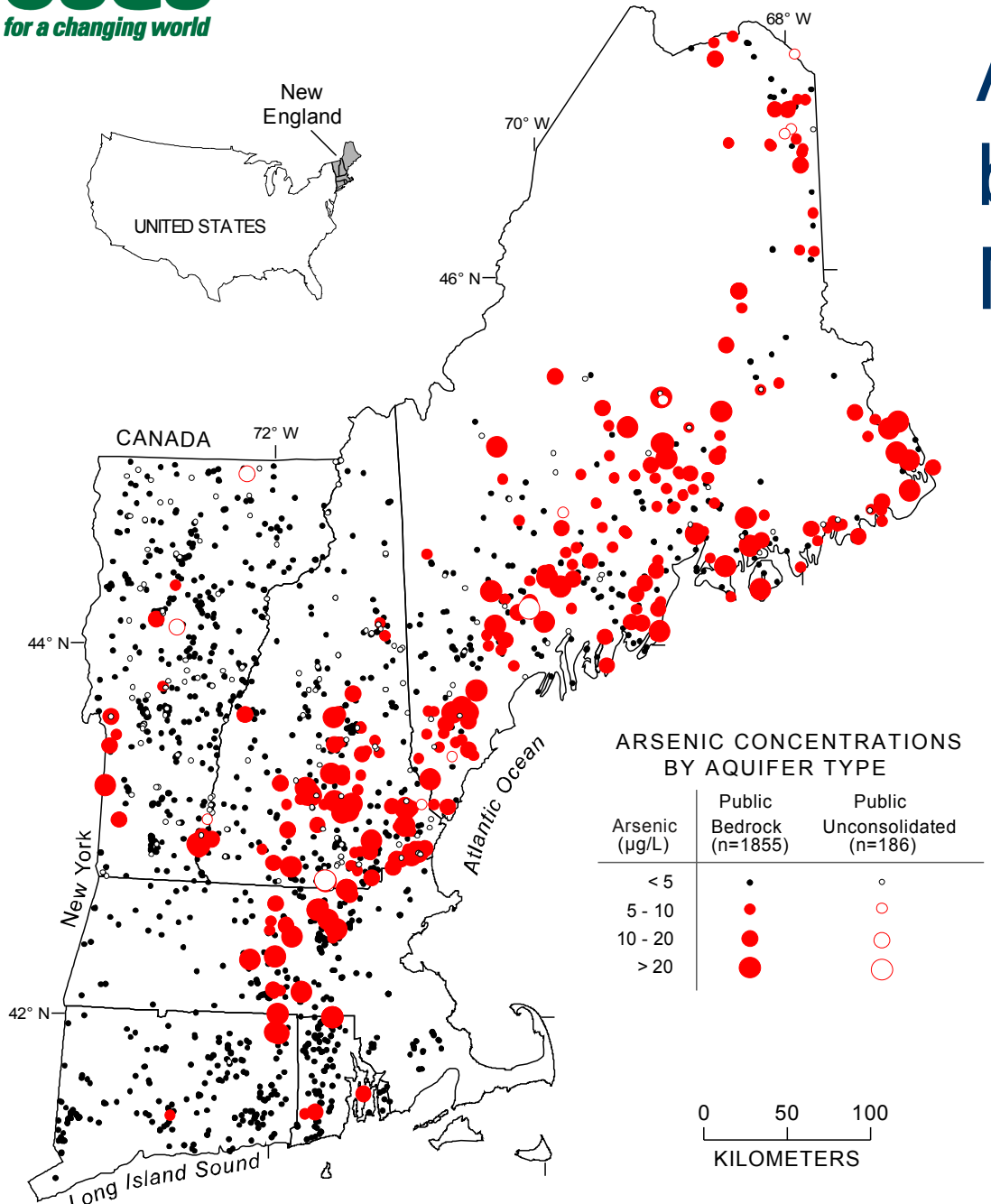
Arsenic in *public* bedrock wells in New England



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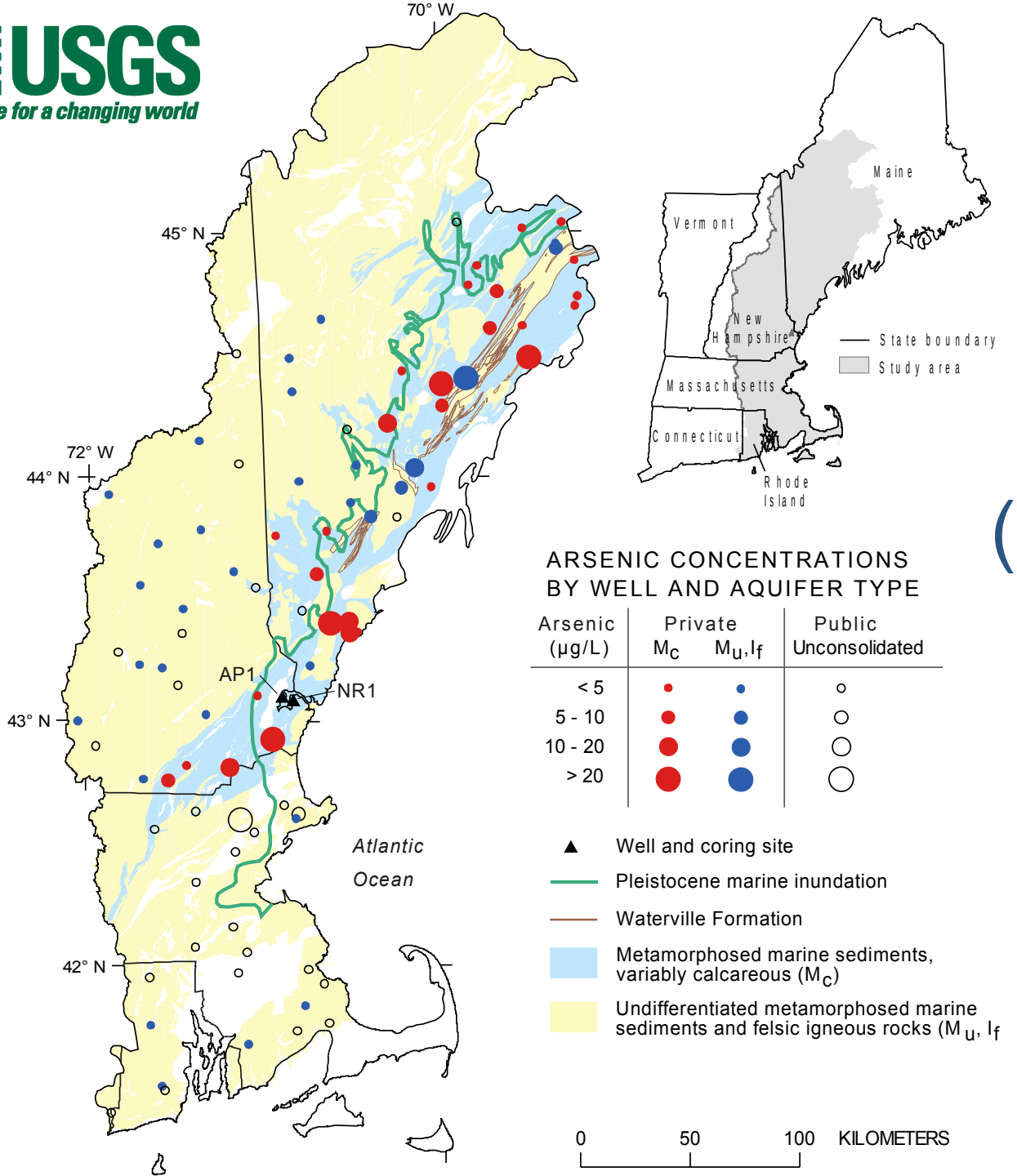
A geologic model for arsenic in ground water (eastern NE)

(Envir. Sci. & Technol., 2003)



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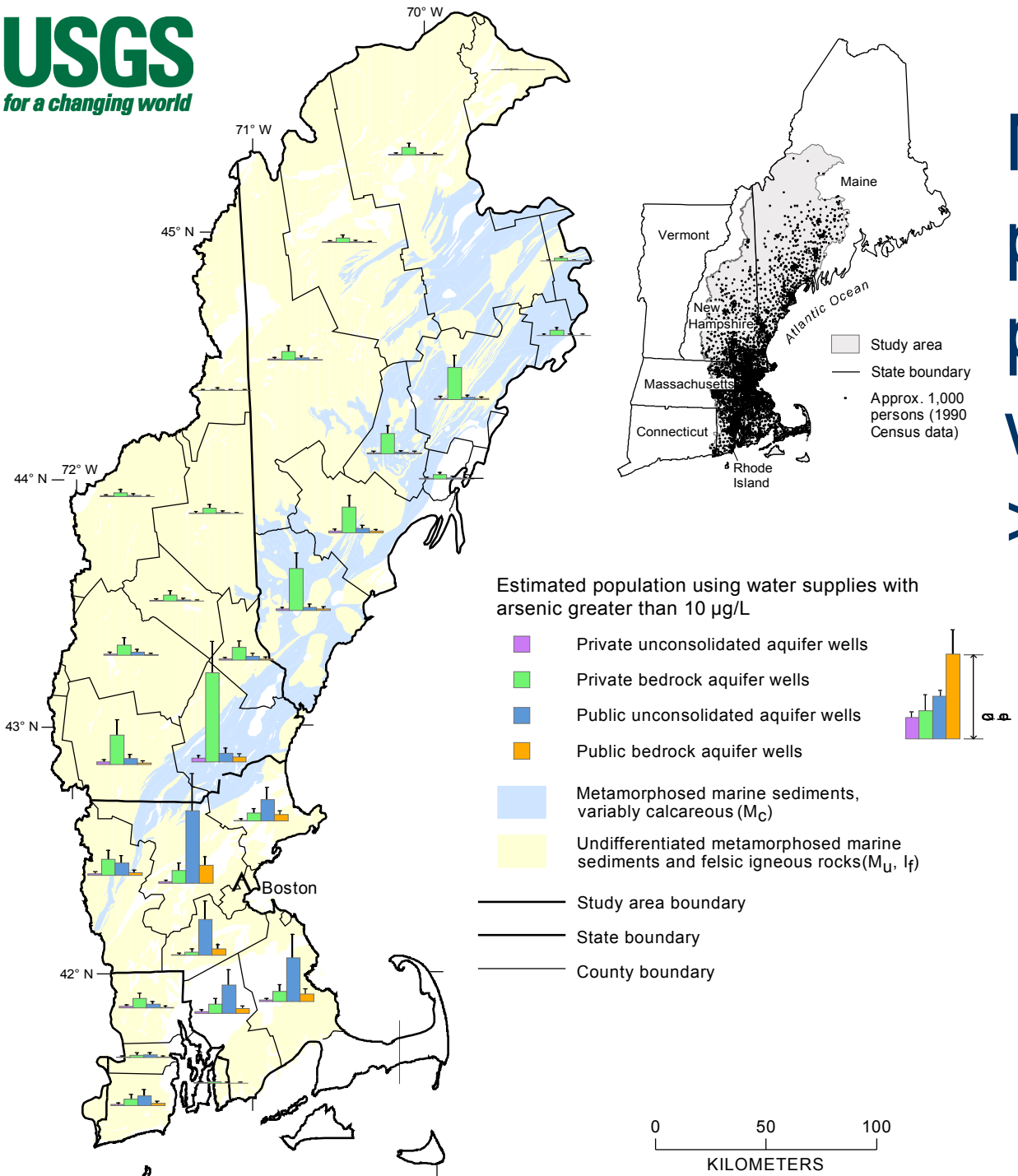
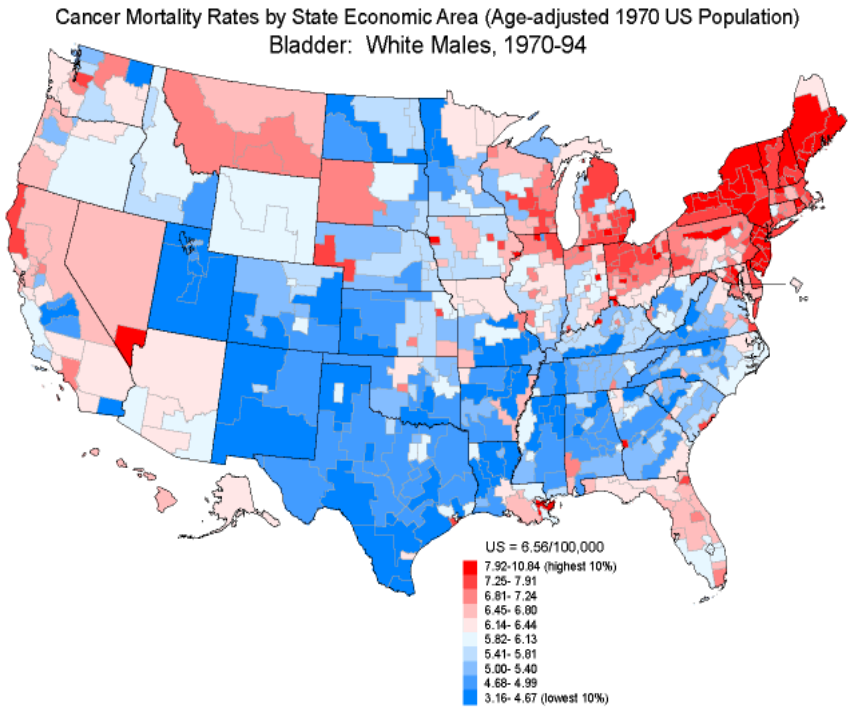
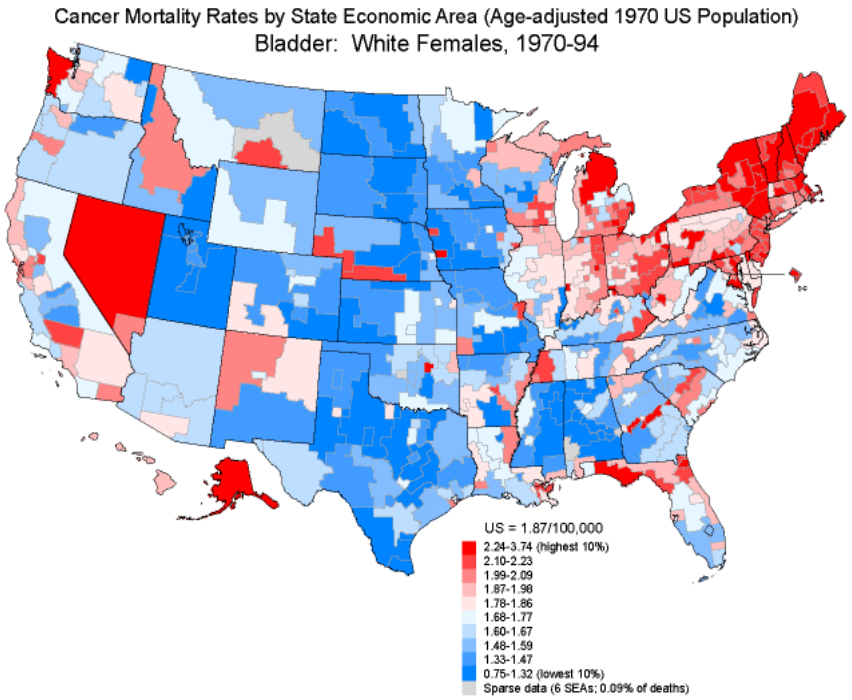
Number of people with private wells with arsenic > 10 ppb



New England Bladder Cancer Study





Males- 1970-94

Females- 1970-94

*Atlas of Cancer Mortality in the United States, 1950-1994, NCI

New England Bladder Cancer Study

- Study location: three states of Northern New England with persistent elevated bladder cancer mortality (Vermont, New Hampshire, and Maine)
- Design: Population-based case-control study
- 3+ years of case ascertainment: 2002-2005
- 1200 cases, 1200 controls
- Interview at the subject's home, with collection of water & biologic samples

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Bladder Cancer in Northern New England: Questionnaire Items

- Demographic information
- Smoking history
- Occupational history
- Food frequency questionnaire
- Medical history
- Other factors
- **Residential & water use histories**

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Estimate arsenic concentrations

- Objective: estimate arsenic concentrations in the water supplies for each subject for each year (lifetime, with priority on previous 40 yrs)

- Current home:
  - use measured arsenic level
- Past homes:
  - use measurement data, if available
  - use arsenic prediction model

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New England arsenic model

- Compile dependent variable (arsenic) data from existing data sources
- Collect new data where arsenic variance is greatest
- Compile explanatory data sets – (GIS mapped variables)
- Build process-based logistic regression model

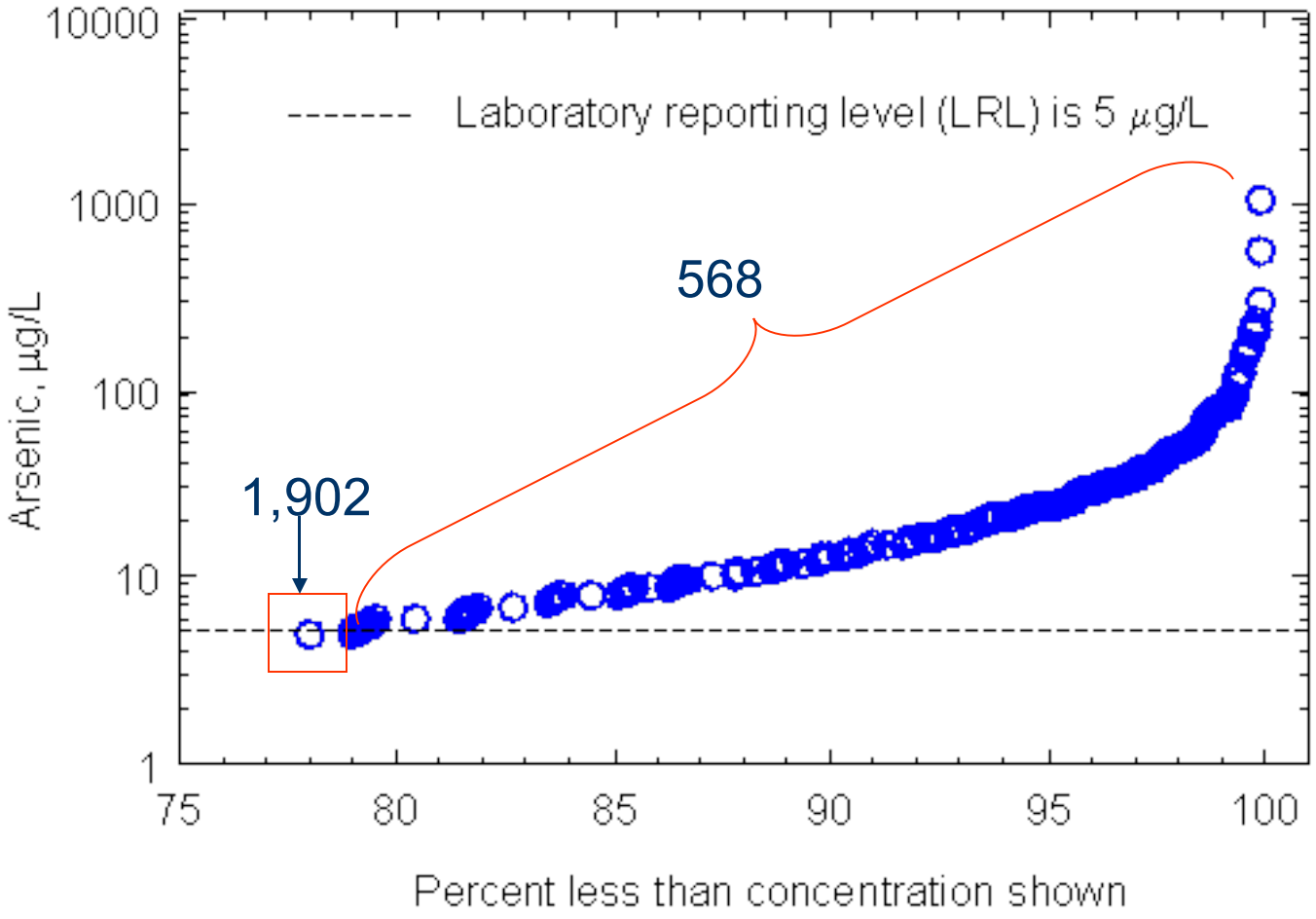
Dependent variable data for Logistic Model

1.	Public water supply data	2,326
2.	USGS NAWQA	117
3.	USGS NWIS	781
4.	USGS southeast NH	355
5.	Other NH private wells	191
6.	Maine private wells	132
		3,902

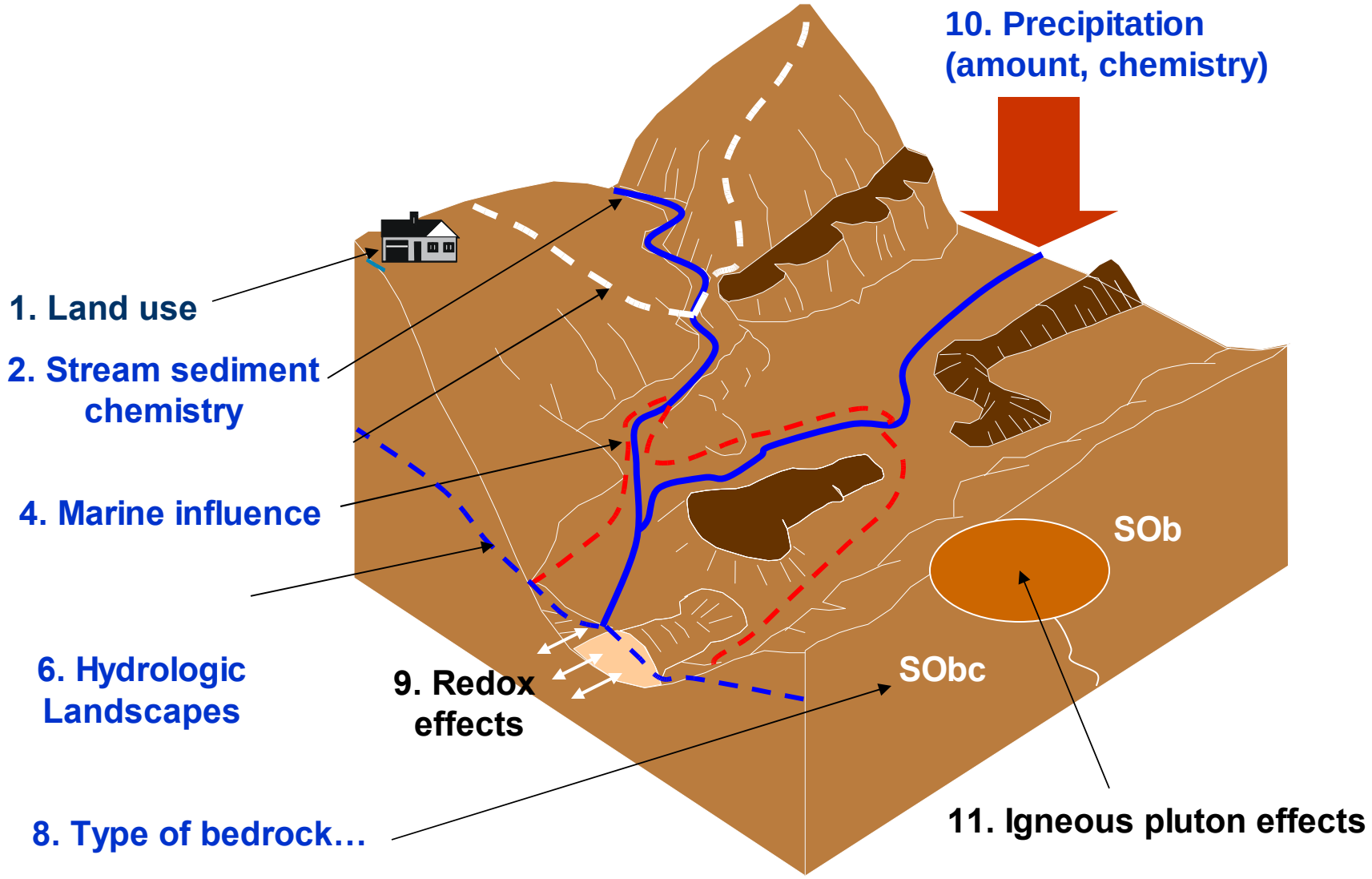
NB: About 60 percent of wells from public water supply monitoring programs

Dependent variable: arsenic in water wells

N=2,470 (78% < 5 µg/L)

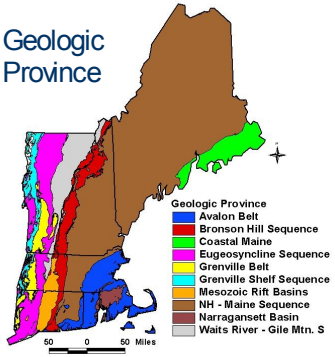


Independent variables – conceptual

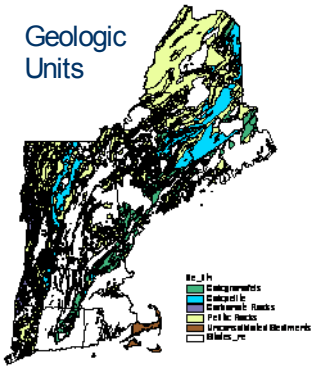


Independent variables – GIS

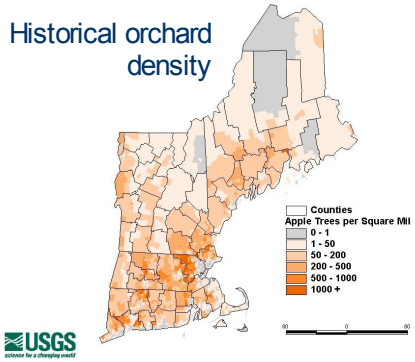
Geologic Province



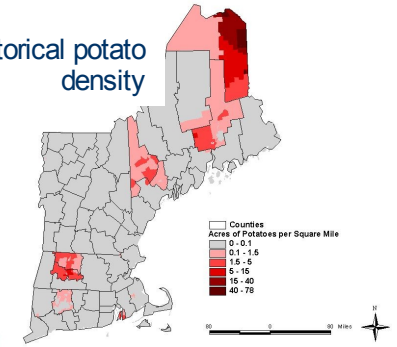
Geologic Units



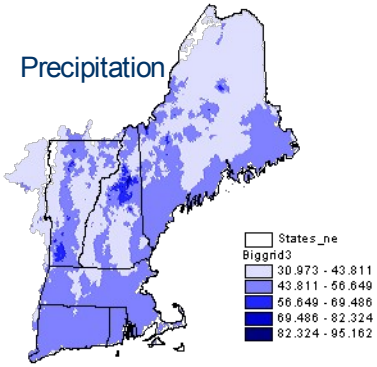
Historical orchard density



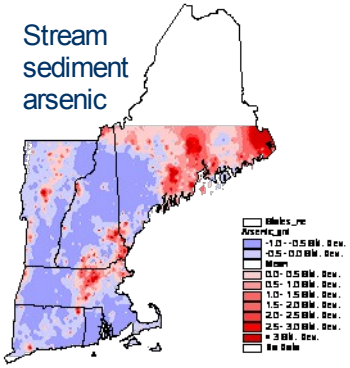
Historical potato density



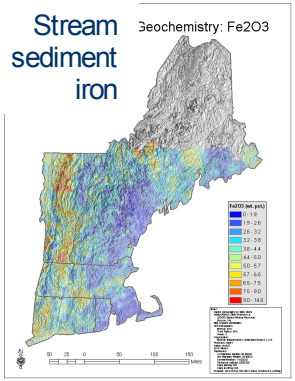
Precipitation



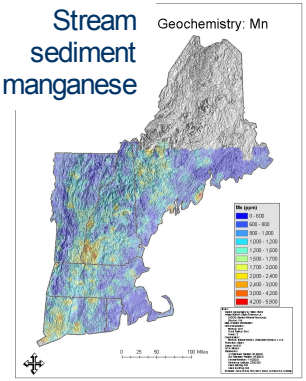
Stream sediment arsenic



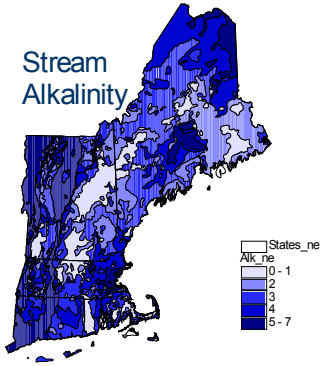
Stream sediment iron



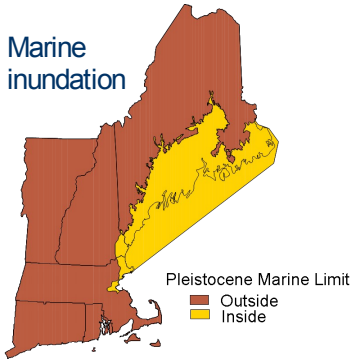
Stream sediment manganese



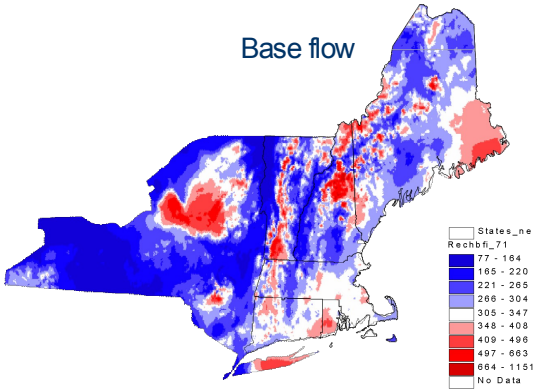
Stream Alkalinity



Marine inundation



Base flow



Variables summary for Logistic Model

VARIABLE	TYPE	EXP(B)	P-VALUE
ARSENIC SOURCES—GEOLOGIC PROVINCE			
Avalon Belt	binary	0.210	<0.0001
Bronson Hill	binary	0.047	0.0026
Mesozoic Basin	binary	2.627	0.0443
Waits River Basin	binary	0.054	0.0042
ARSENIC SOURCES—GEOLOGIC UNIT			
Dc1m - Concord granite	binary	1.878	0.0134
DSm - Madrid Fm	binary	4.515	0.0244
DSrb - Rindgmere Fm	binary	3.821	0.0343
SObc - Berwick Fm, calcareous	binary	3.770	<0.0001
SOec - Eliot Fm, calcareous	binary	13.286	0.0281
SOk - Kittery Fm	binary	6.176	0.0695
Srl - Rangeley Fm	binary	2.320	0.0010
Sspm - Perry Mtn. Fm	binary	3.499	0.0139
Sw - Waterville Fm	binary	2.838	0.0080
SZk - Kittery Fm., Maine	binary	6.176	0.0241
Zmz - Massabesic Gneiss Fm	binary	0.116	0.0033

Variables summary for Logistic Model

VARIABLE	TYPE	EXP(B)	P-VALUE
ARSENIC SOURCES			
Stream sediment as, (ln) mg kg^{-1}	continuous	1.7	<0.0001
GEOCHEMISTRY			
Marine inundation - Pleistocene	binary	2.1	<0.0001
Intrusive granitic pluton category	binary	1.4	0.0069
HYDROLOGY AND LAND USE			
Developed land (500 m radius)	binary	0.6	0.0007
Elevation (1:24,000 scale DEM, m)	continuous	0.9	0.0005
Population density (persons km^{-2})	continuous	0.9	0.0354
Precipitation, mm yr^{-1}	continuous	0.9	<0.0001
Water bodies (500 m radius)	continuous	0.9	0.0023

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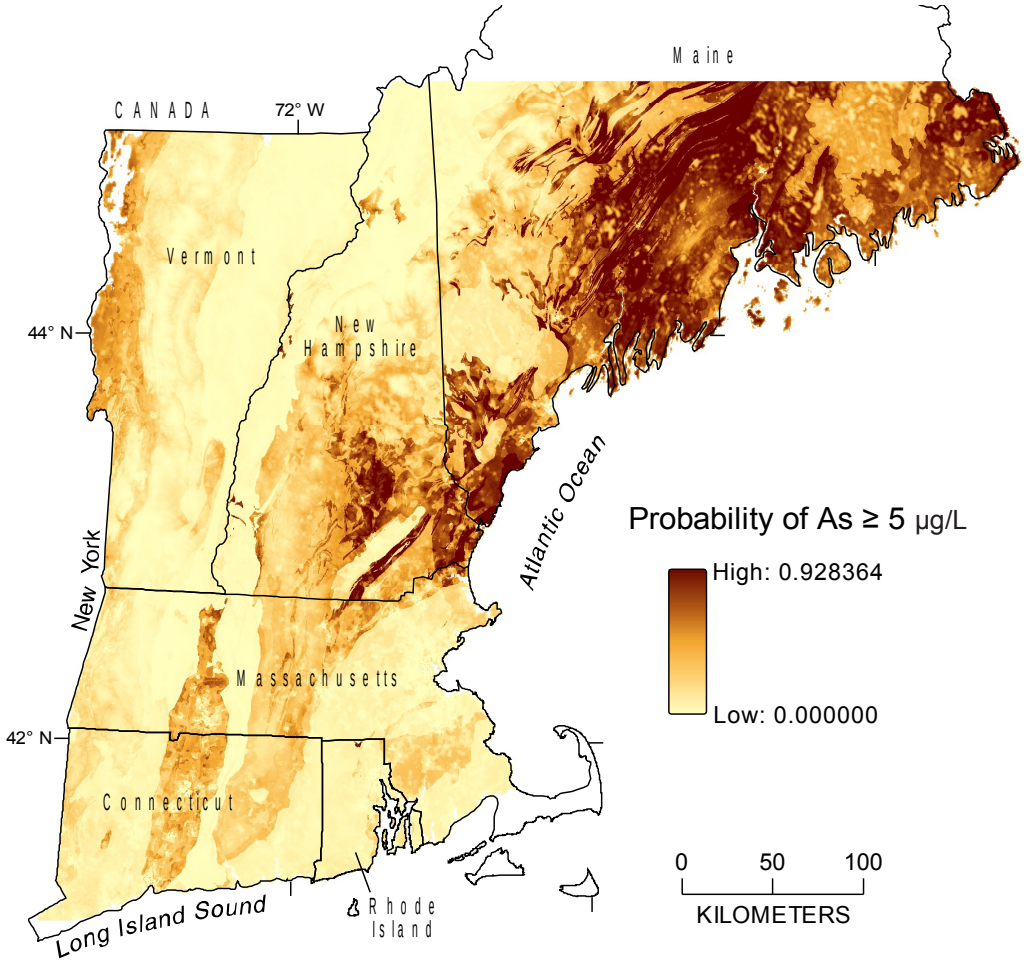
Probability of arsenic ≥ 5 ppb



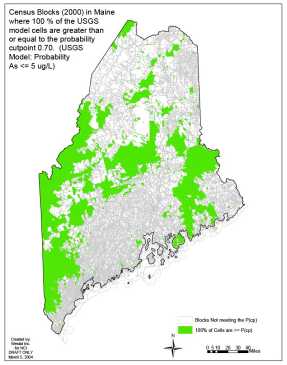
Application of Logistic Model

1. Basis for exposure assessment (currently being converted to a concentration based model)

   True exposure for subject (i) for all years (y):= Σ_y $As_{y(i)}Consumption_{y(i)}$

   (Consumption from subject's Qx data)

4. Use to identify priority areas for sampling of past wells (Low priority where As < 5.0 ug/L)



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Limitations of Logistic Model

- Predicts probabilities rather than concentrations
- Arsenic is highly variable spatially
- Cannot account for independent variables that are not mappable
- Does not address temporal variability

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Summary

- Significant predictive factors include geologic, geochemical, hydrologic, and land use factors
- Can be used to guide sampling design and exposure modeling

2006, Modeling the Probability of Arsenic in Groundwater in New England as a Tool for Exposure Assessment: Environmental Science and Technology, v. 40, no. 11, p. 3578-3585.

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